**ABSTRACT**

**DETECTION, TRACKING, AND CLASSIFICATION OF AIRCRAFT AND BIRDS FROM MULTIROTOR SMALL UNMANNED AIRCRAFT SYSTEMS**

Chester Dolph
Electrical and Computer Engineering,
Old Dominion University, 2022
Director: Professor Dr. Khan Iftekharuddin
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The ability for small Unmanned Aircraft Systems (sUAS) to safely operate beyond visual line of sight (BVLOS) is of great interest to governments, businesses, and scientific research. One critical element for sUAS to operate BVLOS is the capability to avoid other air traffic. While many aircraft will be cooperative and broadcast their locations using Automatic Dependent Surveillance Broadcast (ADS-B), it is expected that many aircraft will remain non-cooperative – meaning they do not communicate position or flight plan to other aircraft. Avoiding mid-air collisions with non-cooperative aircraft is a critical limitation to widespread sUAS flying BVLOS. Examples of non-cooperative traffic de-confliction techniques include ground-based radars, on- board radars, LIDAR, infrared sensors, and optical sensors. Each of these detection modalities has limitations –ground-based sensors require reliable communication between the sUAS and the ground radar to perform traffic deconfliction, on-board radars and LIDARs are often large and heavy relative to sUAS payloads, infrared sensors require a temperature contrast, and vision sensor performance suffers in inclement weather conditions. Current sUAS onboard avoidance systems are not approved for large-scale autonomous operations due to the challenges of the proposed well- clear definitions by regulatory authorities, the need for an avoidance system to address a wide range of flight environments, the need to mitigate many types of aircraft and encounter scenarios, the challenges of sUAS payload requirements, and the development of robust threat detection algorithms. A significant portion of the state of the art only addresses one of these challenges, e.g., vision-based detection of General Aviation (GA) aircraft without context of avoidance models or blue-sky flight conditions with low-clutter background where detection of objects is the least challenging. This work develops novel methods for detection, tracking, and classification of aircraft and birds using onboard vision sensors mounted to a multirotor sUAS. The aerial videos are captured by NASA in coastal Virginia. Analysis is contextualized using proposed avoidance definitions by the Federal Aviation Administration (FAA) and Radio Technical Commission for Aeronautics (RTCA) for self-assured separation. Key contributions of this work include: (i) development of a vision-based detection algorithm for fixed-wing sUAS and GA aircraft with analysis contextualized within self-assured separation definitions, (ii) characterization of a vision- sensor for range performance towards developing a monocular ranging technique, (iii) development of aircraft and bird classifier with improved performance through the integration of adversarial learning, and (iv) the development of an optical-radar fusion system for tracking a multirotor sUAS in a ground to air experiment.